The Main Injector 8 GeV Line Online Model

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1 Introduction

The Main Injector 8 GeV line online model (presently I71) is the ACNET interface to the Main Injector 8 GeV line model. This program provides the user the ability to display and modify parameters associated with a model of the Main Injector 8 GeV line, and to see the effects of those changes.

The program allows the user to:

- Modify the strength of various elements.
- Modify the roll and translational location of various elements.
- Display or plot the calculated Twiss parameters at user-specified locations down the beamline.
- Display a difference between I39 real or file data and calculated orbit data.
- Allow the user to place phase space plots in any location along the beamline and thereby see the phase space distribution of protons when protons are propagated down the beamline.
- Allow the user to place SWICS in any location in the beamline and thereby see the beam profile in X and Y when a distribution of protons is propagated through the machine.
- Change the initial launch conditions including the momentum of the beam coming out of Booster to explore "what-if" conditions.

2 Philosophy of design

There a few program conventions that the programmers have attempted to maintain across the various windows and menus of the program. The units used for the elements are based on the MKS unit system except where this would result in dealing with unusually small numbers. The text that appears on a cyan background is editable. The changes made may not take effect though until a "Send to ..." or "Okay" field is interrupted on. Most transactions with the model are logged in the message window at the bottom of the page. Any text that is bracketted by ♦'s will act as a button, and an interrupt on the text will take a particular action. These buttons normally will be found as titles for columnar data. It should be noted that the user can not make any changes to the real Main Injector 8 GeV line from this program.

3 Main Page

The main page is the page presented to the user when the program starts up. Of all the menu options available, **Initialize**, and **Customize** are the only operating menu buttons. The **Customize** menu is used to select a different model server than the default server, *Reepicheep*. The user will have no need to change this. Other servers can be selected for development purposes.

The **Initialize** menubutton starts the model initialization process. This begins the model using a model of the beamline based on the MAD decks for the layout of most of the elements but with modified quadrupole settings to reflect present (or near-present) running conditions.

After initialization is complete, The other menu buttons become accessible. These will be discussed below.

The model page is the primary function page of the program for the Main Injector 8 GeV line model. From the menubar provided, the user can various actions to take on the MI 8 model. There are a number of menus available to the user: **Initialize**, **Read**, **Calculate**, **Filter**, **Edit** and **Customize**. Each of these menus will be described below.

3.1 Read

The read menu allows the user to execute reading operations of various parameters. This submenu consists of the following choices: **Read I39 file** and **I39 - model orbit**.

The **Read I39 file** and **I39 - model orbit** options are used to read in or manipulate I39 orbit data. The first of the above menu items allows the user to retrieve live I39 BPM flash frame data, or a I39 BPM file. If the user selects the **I39 - model orbit** options the data will be displayed 'raw' or with a reference file subtracted (see **Customize** section). Once files have been selected, any modifications to the initial launch, or the circuits will update the BPM displays with the current orbit subtracted from the BPM file or file difference.

3.2 Calculate

The **Calculate** menu allows the user to calculate and display various beamline parameters. This submenu consists of the following choices: **Twiss Parameters**, **Proton Trajectory** and **Propagate**.

Selecting the Twiss parameters displays the Twiss and dispersion parameters at the locations specified by the filter(s) selected under the **Filter** menu. The user has the option of displaying the Twiss parameters on the main window display or dumping them to an ASCII file with the name (`XCONSOLE$SCRATCH:TWISS_`*date*`.DAT`) for analysis using offline programs. When the data is displayed using the main window, the column titles provide a way for the user to plot all the data in that column on the Lexidata. When cursor control is enabled via the **Customize/Plot Options** menu, the coordinates of the cursor will be displayed.

The **Proton Trajectory** menu item allows the user to calculate the proton trajectory based on the current model configuration and display the information on columnar form at the locations specified by the **Filter** menu.

The **Propagate** menu item informs the model to propagate a proton bunch in the MI 8 GeV line. Unless a phase space plot or a SWIC is displayed, this command will not display any data. The number of protons, the number of turns and their momentum spread can be specified in the **Customize/Bunch Options** menu. The default parameters for the propagated bunch is 200 protons, Horizontal emittance 3 π-mm-mr, Vertical emittance 1 π-mm-mr, and $\frac{dp}{p} = 0\%$. An abort button is provided with the Propagate

command. If a user does abort a Propagate command, the program may take a while to respond back to the user due to the time it takes to propagate a series of protons down the beamline and then check for any user input.

3.3 Filter

The filter menu allows the user to select a combination of device types which represent for what locations the accelerator parameters should be displayed. For example, selecting the **Vertical Corrector** filter will mean that if Twiss parameters are then retrieved from the model, the values of the Twiss parameters at the vertical correctors will be displayed. The selections affect only the display of the data, and in no way affects the calculations. Selecting 'ALL' will retrieve model data for all elements. The user can select a combination of filters (Horizontal and Vertical BPMS, for instance) depending on the interests of the user.

3.4 Edit

The edit menu allows the user to edit elements of the MI 8 GeV line model. This submenu consists of the following choices: **Circuits**, **Individual Elements**, **Insert phase plot**, **Delete phase plot**, **Insert SWIC**, **Delete SWIC**, **Initial Twiss** and **Initial Launch**.

The **Circuits** menu item retrieves a list of magnet circuits in the MI 8 GeV line. A circuit is defined as one or more powered elements with the same ACNET name in the beamline. The user can modify the strength or the alignment of a circuit. One can then calculate the Twiss parameters due to this change or propagate a proton bunch in order to see the effects. The **Individual Elements** menu item allows the user to change individual elements in the MI 8 GeV line. Note that in both cases, the changes don't become effective until the user sends them to the model via the **⧫Send to Model⧫** button.

The **Insert phase plot** and **Delete phase plot** control the insertion and deletion of phase space plots from the model MI 8 GeV beamline. A phase space plot showing all three planes ($x-x', y-y', c\Delta t-\frac{dp}{p}$) can be inserted anywhere in the machines.

The **Insert SWIC** and **Delete SWIC** control the insertion and deletion of SWIC displays from the model MI 8 GeV beamline. A SWIC display

showing a histogram in both the x plane and y plane can be inserted anywhere in the machines.

The **Initial Twiss** menu item, is presently unavailable. The **Initial Launch** menu item allows the user to change the initial particle coordinates (x, x', y, y', and $\frac{dp}{p}$) coming into the beamline.

3.5 Customize

The customize menu allows the user to control different features of the MI 8 GeV line model. This submenu consists of the following choices: **Plot options**, **Select Server**, **Bunch options**, **Phaseplot scale** and **BPM options**.

Under **plot options**, the user can enable or disable the cursor if a plot is active, as well as control the scaling of the plot.

The **Select Server** menu item allows the user to select an alternate model server in the event that the default server is down. This will of course necessitate the re-initialization of the model.

The **Bunch options** menu item allows the user to define the characterisitics of the proton bunch that will be used for the calculations. The user can specify the number of protons, the emittances (in π-mm-mr) and the the $\frac{dp}{p}$ (in %).

The **BPM options** menu item allows the user to define the reference file to be subtracted from subsequent I39 BPM file reads. This allows the user to look or analyze a difference file with the model. Setting the reference file number to -1 disables this subtraction feature. There is also an option to change the BPM scaling in this menu item.

4 Examples of Program use

The following examples are possible uses of the program. They are given to provide the user with an idea of the capabilities of the program and not to define its limitations.

4.1 Graph Twiss parameters of the MI 8 GeV line.

Graphing of the Twiss functions of the MI 8 GeV line, is a straightforward procedure. The following steps will describe the procedure.

- Start up page I71 and initialize the model by selecting the **Initialize** menu button.

- Now the Twiss parameters will be displayed at the locations designated byby the beamline element type(s) selected in the filter menu. For interest-sake, let's display the Twiss parameters at all of the Horizontal BPM locations. Select **Filter** and select the **Horizontal BPM** and de-select the **Markers** and then select **Okay**.

- Now to calulate the Twiss parameters, select **Calculate/Twiss Parameters/Output to screen**. This will begin the calculation and retrieval of the Twiss parameters at the locations we requested.

- With the Twiss parameters displayed, we can scroll up and down to find the particular location of interest, as well as scroll left and right to see both the horizontal and vertical Twiss parameters.

- We can plot the Horizontal beta function down the beamline by selecting ♦ **beta** ♦ and then selecting the **Graph plot** feature. A plot of the Horizontal Twiss function down the beamline will be displayed on the Lexidata.

- If we want to get a better idea of the value at one of the peaks, we can enable the cursor and put the cursor on a peak. Under the **Customize** menu, select **Plot Options/Enable Cursor**. A window will appear on the PA and a cursor will appear on the Lexidata. The PA window will display the plot coordinates of the cursor. The cursor can be turned off by selecting **Customize/Plot Options/Disable Cursor**.

4.2 Inspecting the phase space at the beginning and end of the beamline

This example will show the shape of phase space at MP02 as well as at Q852.

- Start up page I71and initialize the model by selecting the **Initialize** menu button.

- We will need to put a phase plot at the MP02 magnet. So lets make sure the filter is set to "Markers" only (select **Filter** and make sure "Markers" is in green).

- Select **Edit/Insert phase plot**. A window will come up listing all the markers in the MI 8 GeV line. At the top of the window should be MP02. This is a marker placed at the front of MP02. A separate phase space plot will appear on your console. If this demo is being run on a workstation other than a VAX console, there may be problems with permissions for other machines to place X-window clients on your screen. For a unix environment, you may need to issue the command "xhost +reepicheep.fnal.gov". For other environments, I don't know.

  The new window that has come up is a phase space display, showing, the two transverse ($x-x'$ and $y-y'$) and one longitudinal ($c\Delta t-\frac{dp}{p}$) phase space regions.

- Now we'll use another type of beam display.

- Select **Edit/Insert SWIC**. A listing of all the Select **MQ852**. This is the marker at the same location as the Q852 at the end of the beamline.

- Begin the propagation of the protons down the beamline by selecting **Calculate/Propagate**. As beam makes it down the beamline, you should see the MP02 phase plot fill up in the center of $x-x'$ and $y-y'$. Don't dispair if you don't see anything right off. It takes some time to calculate the proton distribution and track them down the beamline.

4.3 Analyzing BPM difference data

This example demonstrate how analyze BPM data in order to attempt to figure out what may be wrong with the beamline.

- Since BPM files are somewhat 'volatile' I will use an example of some data taken during the commissioning of the beamline. Your results may vary. The idea is to start off with a BPM display of the unperturbed accelerator. Then a correction element is changed and another BPM display is taken. If the two BPM displays are subtracted, only the effect from the corrector changed is seen. This allows us to analyze the beamline without knowing the values of all the correctors.

- Start up page I71 and initialize the model by selecting the **Initialize** menu button.

- Set the BPM reference file by selecting **Customize/BPM options** and type 75 for the reference file. Select **Okay** to close the window.

- Select the BPM file to analyze by selecting **Read/I39 - orbit/I39 BPM file** and select file 77. This data was taken with a horizontal one-bump with HT802 set at 3 amps. A display of the horizontal and vertical BPM data should be displayed. The model is displayed in red, the BPM data in green, and the difference in yellow. Note that with the data in these files, the first 4 BPMS in each plane were very noisy and should be disregarded.

- Now put the bump in the model. Select **Edit/Circuits** and scroll down to find B:HT802. Eventually the program will allow the user to switch between MKS and engineering units (amps) but for now the user must do the conversion. A change of +3 amps corresponds to a setting of -.3501 mradians. Type this in and interrupt. WHen you do, the model will calculate a new orbit and update the BPM displays.

- Now we are set to try to find out what is different between the model and the beamline. Notice the difference between the model and the BPM data around BPM 808.

- Change the $\frac{dp}{p}$ to +0.012 and send that. The deviation of the model with the BPM data now doesn't occur until BPM Q810.

- If you now change the values of I:Q810A and I:Q810B to 2.52 $\frac{T}{m}$, you'll see the difference (yellow trace) tend to zero. By continuing in this fashion, one can explore mis-alignments and polarity reversals by taking a little BPM data. It should be noted that the vertical plane is almost flat. The slight ripple could be due to a tilted quadrupole which will have a tendency to couple the oscillations into the vertical plane.